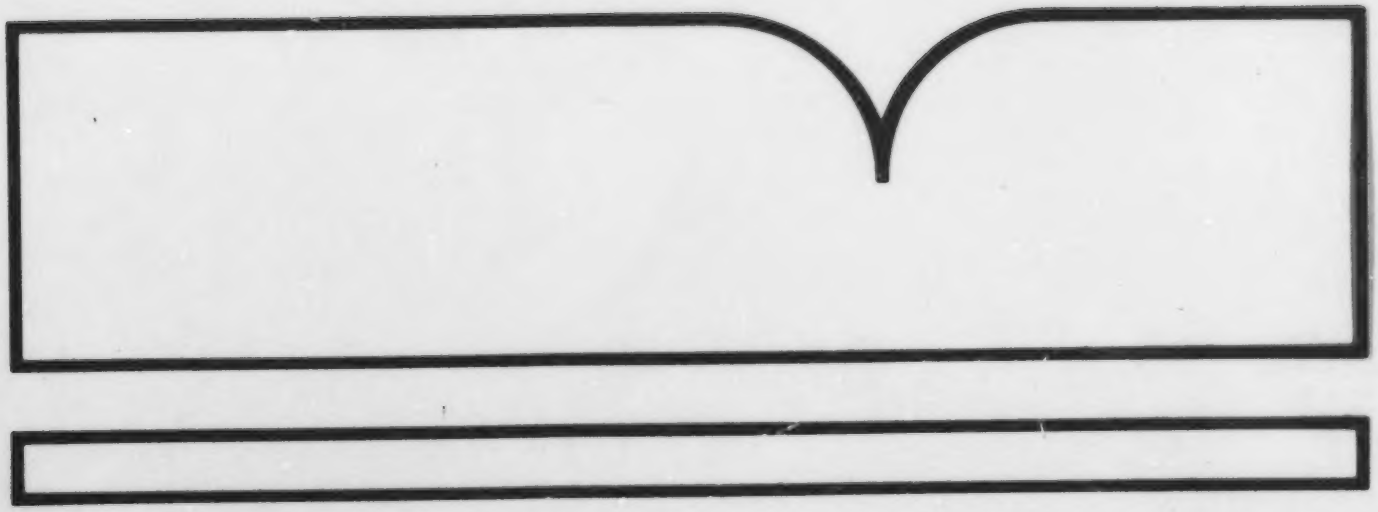
PB84-170679

Emergency Response Equipment to Clean Up Hazardous Chemical Releases at Spills and Uncontrolled Waste Sites

(U.S.) Municipal Environmental Research Lab.-
Cincinnati, Edison, NJ

1982



U.S. Department of Commerce
National Technical Information Service
NTIS

PB84-170679

EPA-600/D-82-348
1982

EMERGENCY RESPONSE EQUIPMENT TO CLEAN UP HAZARDOUS CHEMICAL RELEASES AT SPILLS AND UNCONTROLLED WASTE SITES

by

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/D-82-348		PB84-170679

4. TITLE AND SUBTITLE	5. REPORT DATE
EMERGENCY RESPONSE EQUIPMENT TO CLEAN UP HAZARDOUS CHEMICAL RELEASES AT SPILLS AND UNCONTROLLED WASTE SITES	1982
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Ira Wilder	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Oil & Hazardous Materials Spills Branch Solid & Hazardous Waste Research Division Municipal Environmental Research Laboratory Edison, New Jersey 08837	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Municipal Environmental Research Laboratory-Cin., OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/600/14
15. SUPPLEMENTARY NOTES	

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
		22
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (9-73)

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ABSTRACT

This paper reviews some of the research activities of the U.S. Environmental Protection Agency (EPA) regarding the development of emergency response equipment to control hazardous chemical releases. Several devices and systems have been developed by EPA for environmental emergencies involving spills and uncontrolled waste sites. Many of these have already been made available commercially by industry, including a mobile physical/chemical treatment system for processing contaminated water at hazardous incidents and a mobile laboratory for on-site chemical analyses. Other operationally-ready devices addressed in this paper include: a mobile stream diversion system for isolating segments of small streams to facilitate the removal of contaminated sediments; a portable back-pack polyurethane foam diking system for the containment of spilled chemicals; and an acoustic emission-based spill alert device for detecting imminent dike failure at lagoons containing toxic and hazardous wastes. Prototypical equipment, described in this paper, which are now undergoing shakedown testing and evaluation include: a mobile soils washing system for extracting spilled materials from excavated soils on site; and a mobile, field-use incineration system for the thermal destruction of toxic organic compounds.

INTRODUCTION

Problem

Billions of metric tons of oils and hazardous chemicals are produced and handled annually in the United States. These materials range from gasoline and fuel oils, to vegetable oils, sulfuric acid, lye, chlorine and chlorinated compounds, cyanides and isocyanates, and include hundreds of millions of kilograms of toxic pesticides and pharmaceuticals. Millions of metric tons

are released into the water, land, and air environment each year--often with catastrophic consequences--due to spills resulting from ship, truck and train accidents, equipment malfunction, transfer line failure, broken pipelines, lagoon dike rupture, overfilling, leaking storage tanks, container puncture, flood, earthquake, fire and explosion.

Similarly, millions of metric tons of hazardous wastes are generated in this country each year from manufacturing, processing, and other industrial operations. Disposal of this substantive quantity of waste is a matter of great public concern in the wake of numerous case histories involving negligent dumping practices resulting in several instances of contamination that have severely damaged the environment and threatened human life. Perhaps the most dramatic example of inadequate disposal of hazardous chemical wastes occurred near Niagara Falls, New York, where hundreds of families living along an abandoned waste disposal site, known as Love Canal, had to permanently evacuate their homes when the toxic chemicals migrated from the site and seeped through the ground into their basements.

Legislative Background

The U.S. Congress addressed the problem of oil and hazardous material spills in Public Law 95-217, the Clean Water Act (CWA) of 1977, and its predecessor statute, Public Law 92-500, the Water Quality Improvement Act of 1972, which authorize the Federal Government to take emergency response action when oils and specially designated hazardous substances are discharged into navigable waters (1). These statutes, however, are seriously limited in their authority to deal with the variety of problems caused by releases of hazardous substances onto land or into groundwater and air.

Public Law 94-580, the Resource Conservation and Recovery Act (RCRA) of 1976, was the first comprehensive Federal legislation to deal with the hazardous waste issue. RCRA establishes a regulatory system to track hazardous wastes from the time of generation to disposal. It requires safe and secure procedures to be used in treating, storing, and disposing of hazardous wastes and is designed to prevent the creation of new Love Canals in the future. RCRA, however, does not permit the government to respond directly to the problems caused by improper (uncontrolled) hazardous waste disposal sites already in existence.

Legal authority to overcome the limitations of both CWA and RCRA was provided in 1980 by the enactment of Public Law 96-510, the Comprehensive Environmental Response, Compensation, and Liability Act (commonly known as Superfund) (2) which authorizes federal emergency response to any hazardous substance release into the environment which endangers public health and welfare--including the cleanup of uncontrolled hazardous waste sites and the mitigation of spills not only in navigable waters, but also in groundwaters, soils, sediments, and the atmosphere.

RESEARCH AND DEVELOPMENT

Successful implementation of the Superfund legislation, as well as the Clean Water Act and the Resource Conservation and Recovery Act, requires major

research and development efforts. Controlling and cleaning up hazardous substances is a relatively complex field. Specialized equipment and techniques are needed in order to respond quickly and effectively to emergencies and to dispose of the materials in an environmentally safe manner. Both industry and the government are working diligently to learn more about controlling these materials and to develop appropriate cleanup devices and equipment. Within the U.S. Environmental Protection Agency (EPA), the Municipal Environmental Research Laboratory (MERL) has the lead role for research and development related to hazardous waste environmental emergencies. Through a program at its Oil and Hazardous Materials Spills Branch in Edison, New Jersey, MERL is developing prototype equipment and experimental techniques for the prevention, control, and abatement of multi-media pollution from hazardous chemical spills and mismanaged hazardous waste disposal sites.

The main thrust of the program centers around emergency response research to develop the tools to remove the immediate threat of a hazardous material

Figure 1. Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT), the world's largest facility for the environmentally safe testing of spill cleanup methods and technologies.

incident in order to control the emergency and protect human health and the environment. A major testing facility of the program is the Oil and Hazardous Materials Simulated Environmental Test Tank (OHMSETT), which consists chiefly of a 9.8 million liter (2.6 million gallon) concrete tank with mobile bridges, a wave generator, and a simulated beach (Figure 1). OHMSETT is the only facility in the world of its kind for the testing, evaluation, and development of full-scale spill cleanup equipment, devices, and systems under controlled, environmentally safe and reproducible conditions (3,4).

Development of hardware and techniques is carried out from the concept stage through the prototype stage to field testing and demonstration. A major objective of the program is to demonstrate the applicability of the prototypical equipment at spills and waste sites throughout the country, thereby stimulating the commercial adoption or adaptation of the devices and encouraging private firms to manufacture or use similar equipment.

Equipment or Systems Currently Field Ready

Several prototypical emergency response devices have been developed, tested, evaluated, and demonstrated to the point where they are fully operational (5). Examples of some of these field-ready devices follow:

Mobile Physical/Chemical Treatment System

This device (Figure 2) is designed to remove hazardous chemicals from water by a variety of physical/chemical treatment steps employed in the

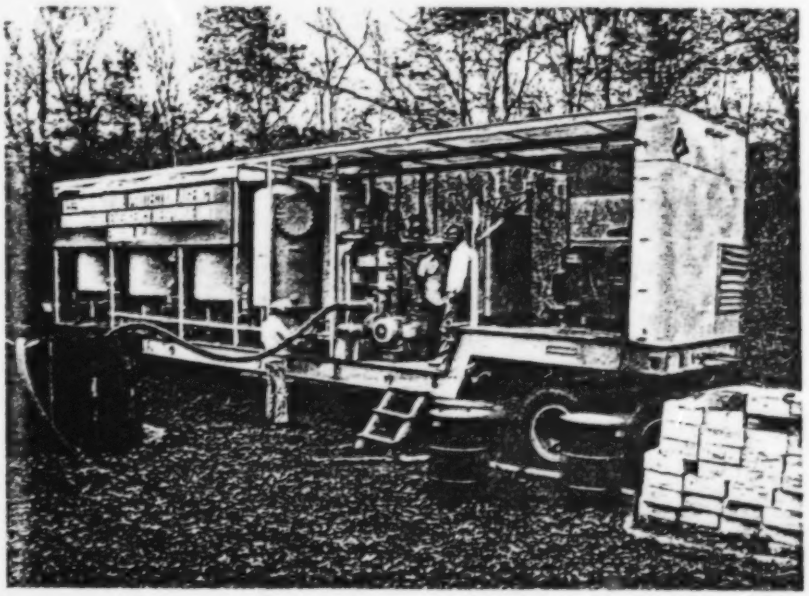

Figure 2. Mobile physical/chemical treatment system for processing contaminated water.

field. It contains equipment for coagulating and settling suspended solids, filtering very fine particulates, and adsorbing dissolved organic contaminents using granular activated carbon. Mounted on a 13.7-m (45-ft) drop deck trailer, the system (6) incorporates three mixed-media filters, three pressure carbon columns (which may be used in parallel or in series), pumps, piping controls, and a 100-KW diesel generator. A support trailer is equipped with additional pumps and several collapsible rubber tanks which serve as sedimentation, chemical reaction, and storage containers. Contaminated water can be processed at flow rates between 379 and 2270-liters (100 to 600-gallons) per minute. The system has been used at more than 30 cleanups of uncontrolled hazardous waste sites and spills of hazardous materials around the country. Commercial units patterned after the EPA system are now routinely employed.

Mobile Decontamination Station

This 12.2-m (40-ft) trailer (Figure 3) is engineered to provide on-site safety support for emergency response personnel. It is intended to ensure that exposed personnel do not leave the site without a proper washdown and clothing change. The unit is placed at the boundary of a cleanup site, and all personnel are required to pass through it when entering and leaving the site. The trailer is divided into three compartments: [1] a "clean" room with lockers for storing street clothing; [2] a shower room; and [3] a "contaminated" room with lockers for work clothing. This room also includes a clothes washer and dryer. The decontamination station is equipped with a fresh water supply and holding tanks for waste water which must be processed prior to discharge. The unit has already been used in the field in support of cleanup activities, and has been duplicated by a commercial spill cleanup contractor.

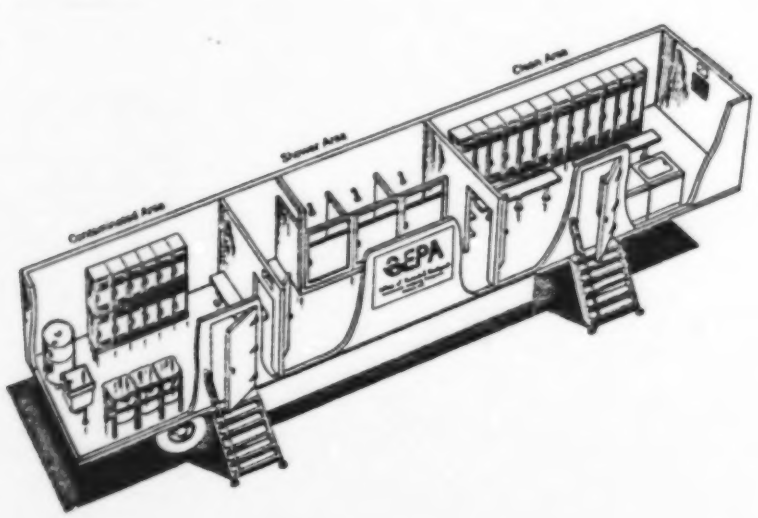

Figure 3. Mobile decontamination station for use of field personnel at cleanup activities involving toxic materials.

Mobile Laboratory

This unit, contained within a 10.7-m (35-ft) semi-trailer (Figure 4), is designed to provide analytical services during the cleanup of hazardous materials at spills and uncontrolled waste sites (7). Having analytical capabilities at the field site avoids delays inherent in shipping samples to a central laboratory. The mobile laboratory contains a broad range of sophisticated instrumentation, including a gas chromatograph/mass spectrometer (GC/MS), computerized gas chromatographs, an atomic absorption spectrometer, infrared and fluorescence spectrometers, and other highly sensitive analytical tools. Special sample processing techniques and glove boxes permit safe handling of high concentrations of toxic chemicals. During the past few years, the mobile laboratory has been used to perform several thousand sample analyses in a variety of emergency response situations. The laboratory has been used as a model by a number of spill cleanup contractors who have built similar mobile units for commercial application.

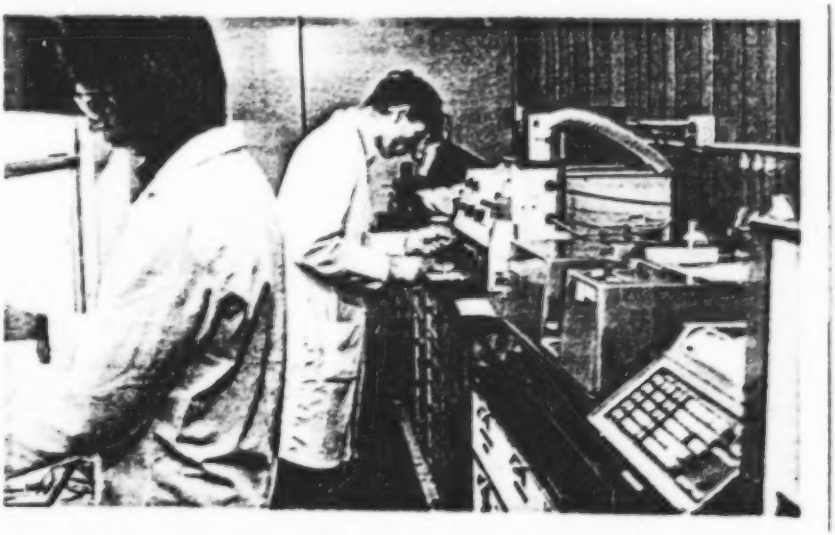

Figure 4. Mobile laboratory to provide analytical services at emergency incidents involving hazardous chemicals.

Acoustic Emission Monitoring Device

This device (Figure 5) is designed to provide an early warning of potential failure to earthen-dams containing hazardous materials (8). Earthen-dam ponds can be found at almost any hazardous waste site in the United States. Many of these impoundments are unstable and, with slight overstressing (such as from heavy rains), may collapse and spill their contents into the environment with potentially drastic consequences. The acoustic emission monitoring device detects instability in earthen dikes by measuring noises generated by soil particle movement. The intensity and frequency of these sounds (acoustic emissions) has been correlated with stress levels for various soils and,

therefore, can be used to indicate stability of dike structures. Acoustic emissions are transmitted to the surface of the dike through metal rods (waveguides) inserted into the impoundment wall. These sounds are converted to electrical signals which are amplified and recorded for analyses. The device, whicn has been commercialized in at least three versions, has received wide recognition as a simple, portable, inexpensive tool for assessing impoundment stability and preventing spills.

Figure 5. Acoustic emission monitoring device for detecting imminent dike failure at lagoons containing toxic and hazardous wastes.

Foam Dike System

This system (Figure 6) is designed to provide a rapid response method for containing or diverting the flow of many spilled hazardous chemicals (9,10). The diking unit consists of an 18-kg (40-lb) back-pack device that generates approximately 0.8-m^3 (30-ft^3) of two-component, very rapid set-up polyurethane foam. Larger sized commercially available units are capable of delivering 1.8-m^3 (65-ft^3) of foam which provides sufficient material to construct a barrier 0.3-m (1-ft) high by 0.3-m (1-ft) wide by 6-m (20-ft) in diameter,

which could impound approximately 7570-liters (2000-gallons) of spilled hazardous liquid. The polyurethane foam adheres well to most dry surfaces (pavement, earth, etc.) for making stable dikes, and can also be used to plug storm drains on streets to prevent spilled hazardous materials from entering sewer systems. The diking unit has been designed as a compact, portable device to be carried by individual operators such as truck drivers or railroad train personnel. Several fire departments in this country have already used the foam diking system in emergency response operations involving hazardous substance releases.

Figure 6. Foam dike system for the emergency containment of spilled hazardous chemicals.

Mobile Stream Diversion System

The system (Figure 7) is intended to isolate segments of small streams so that contaminated sediments can be removed easily with mechanical earthmoving equipment (11). This approach is an alternative to dredging which typically requires extensive water treatment to remove contaminants that become suspended or dissolved during the pumping operation. Dredging also often leads to the downstream spread of the contaminant as a result of resuspension of bottom muds and silts. Isolation of a contaminated stream is accomplished by damming the stream above the impacted area and bypassing the normal stream flow. The stream diversion technique permits the spill-impacted segment to dry, thus facilitating mechanical cleanup. The major components of the system are booster pumps, submersible pumps, generators, a crane, and aluminum irrigation pipe. The system is designed to bypass the flow (up to 0.37-m^3/s [13-ft^3/s]) of a small stream for distances up to 914-m (3000-ft). An alternative use of the mobile stream diversion system is to divert or reroute surface runoff water around a highly contaminated hazardous waste site and prevent the spread of contamination to areas down gradient of the site.

Figure 7. Mobile stream diversion system for isolating segments of small streams to facilitate the removal of contaminated sediments.

Hazardous Materials Spill Warning System

This in-stream system (12), which is capable of detecting a variety of spilled hazardous materials in waterways, is housed in an air-conditioned

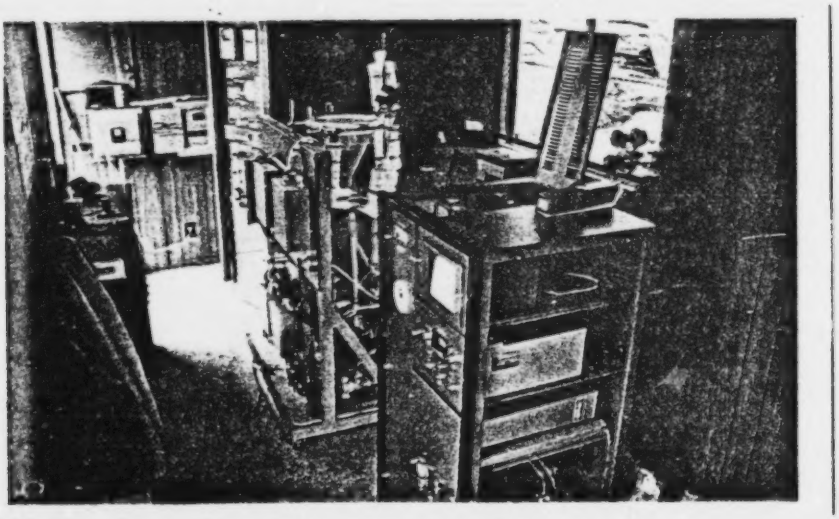

Figure 8. Hazardous materials spill warning system for the continuous in-stream detection of a broad variety of spilled hazardous chemicals in water.

8.2-m (27-ft) automotive trailer (Figure 8). The system operates continuously at an unattended station, without maintenance, for a period of 14 days. A submersible pump in the watercourse supplies uninterrupted water samples to instrument consoles in the trailer. The consoles contain the following: [1] pH, electrical conductivity and oxidation-reduction potential sensors for the detection of acids and bases, ionic compounds, and oxidizing and reducing substances, respectively; [2] a total organic carbon analyzer with a built-in recorder for the detection of organic compounds; [3] a differential ultraviolet absorptimeter for the detection of aromatic compounds; and [4] a control console with strip chart recorders. The hazardous materials spill warning system has already been demonstrated in the field to monitor discharges from uncontrolled hazardous waste sites.

Equipment or Systems Currently Under Test and Evaluation

A number of prototypical emergency response systems are now undergoing final shakedown testing and evaluation prior to full-scale field trials. Examples of some of these systems follow:

Mobile Incineration System

This system (13) was developed for field use to destroy hazardous organic substances collected from cleanup operations at spills and uncontrolled hazardous waste sites. The unit is designed to EPA's PCB destruction specifications (under Public Law 94-469, the Toxic Substances Control Act of 1976) to provide state-of-the-art thermal detoxification of long-lived, refractory organic compounds. Hazardous substances that can be incinerated, for example, include compounds containing chlorine and phosphorus (such as PCB's, kepone, dioxins, and organophosphate pesticides) which may be in pure form, in solution, in sludges, or in soils.

The mobile incinerator consists of four over-the-road trailers (Figure 9) with specialized combustion equipment, air pollution control devices, and monitoring instrumentation. Organic wastes are fully vaporized and completely or partially oxidized at 982°C (1800°F) in a refractory lined rotary kiln. Off-gases are passed through a secondary combustion chamber at 1204°C (2200°F) where thermal decomposition of the contaminants is completed. Acid gases and particulates generated by the combustion process are removed in the system's sophisticated air pollution control apparatus. A comprehensive monitoring system is used to analyze the flue and stack gases for combustion and emission components and is designed to automatically halt the feeding of waste to the incinerator if gas emissions exceed acceptable levels. Design processing rates for the incinerator are 4080-kg/hr (9000-lb/hr) of contaminated dry sand, or 680-kg/hr (1500-lb/hr) of contaminated water, or 284-l/hr (75-gal/hr) of contaminated fuel oil.

A series of test burns with fuel oil has already been completed. In order to systematically evaluate the equipment, PCB trial burns are currently underway. These trials are intended to demonstrate the incinerator's ability to meet or exceed the performance requirements established by Federal, State, and municipal regulations. After the trials, the system will be demonstrated at several hazardous waste sites around the country.

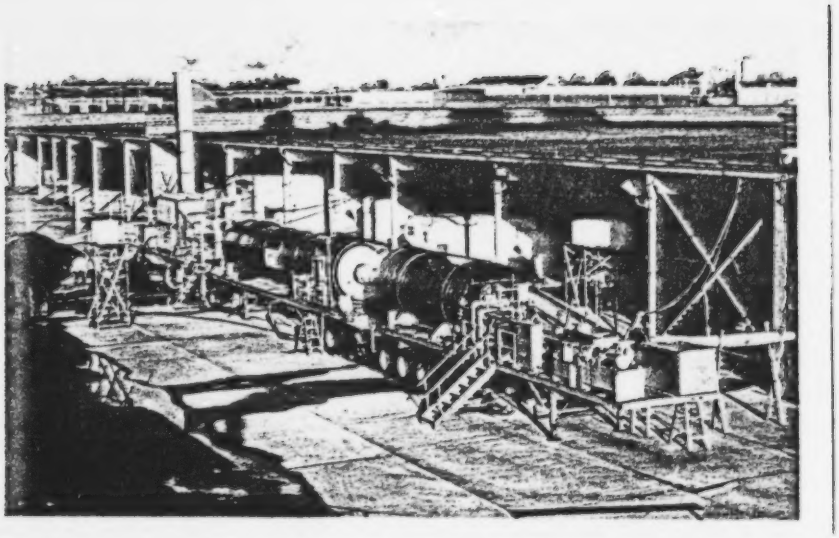

Figure 9. Mobile incineration system for the on-site destruction of refractory organic compounds.

Mobile Carbon Regeneration System

Waters contaminated with hazardous substances can now be cleaned with water purification equipment such as the EPA mobile physical/chemical treatment system (discussed above). Systems of this nature, which utilize granular activated carbon to adsorb the organic contaminants from the water, can be made more cost-effective with on-site regeneration of the spent carbon--thereby eliminating the problems associated with the transportation of contaminated carbon to a secure landfill or an off-site regeneration facility.

The mobile carbon regeneration system (Figure 10) provides a safe and effective method for detoxifying/regenerating contaminated carbon at the cleanup site. The system (14), mounted on a 13.7-m (45-ft) semi-trailer, contains a rotary kiln that heats the carbon in a slightly reducing atmosphere to about 982°C (1800°F) and releases the adsorbed contaminants as a vapor. (The atmosphere in the kiln is conditioned with water to enhance reactivation of the carbon.) The vapor passes into a secondary combustion chamber where it is totally decomposed. The flue gases are quenched with water sprays and scrubbed with alkaline solution to neutralize acids and remove particulates before venting to the atmosphere. Once the carbon is cooled with water, it is ready for reuse. The design processing rate for the carbon regenerator is 45.4-kg/hr (100-lb/hr) of dry granular activated carbon with 90% of the carbon's adsorption capacity restored after regeneration.

The mobile carbon regeneration system is now undergoing comprehensive shakedown testing and evaluation, and is expected to be ready for field demonstration during 1983.

Figure 10. Mobile carbon regeneration system for field use in reactivating spent granular activated carbon used in spill or waste site cleanup operations.

Mobile Soils Washing System

This system (currently under development) is being designed for on-site removal of a broad range of hazardous materials from excavated soils (15). The soils washer is expected to be an economical alternative to the current practice of hauling contaminated soils off site to a landfill, and replacing the excavated volume with fresh soil on site. The system will be capable of extracting contaminants from soils--"artificially leaching" the soil using a water-based cleaning agent--and thereby enabling operators to leave the treated soil on site. To accomplish this, the soil is passed through a rotating drum screen water knife soil scrubber where soil lumps are broken apart by intense jets of water, and chemicals are stripped from soil particles. The resulting soil slurry is fed into a 4-stage counter-current chemical extractor (Figure 11). Each stage consists of a mixing, froth-flotation cell connected in series with hydrocyclones which centrifugally separate solids from liquids. The soil particles are agitated repeatedly in washing fluid and are progressively decontaminated as they flow through each stage. The cleansed soil is then returned to the site. The extracted hazardous contaminants are separated from the washing fluid using physical/chemical treatment procedures (flocculation, sedimentation, carbon adsorption, etc.). The cleaned washing fluid is recirculated while the separated and concentrated contaminants are disposed of by appropriate means.

The prototype soils washing system will be capable of processing 3 to 14-m^3 (4 to 18-yd^3) of contaminated soil per hour, depending on the soil particle size and the nature of the contaminant. The device is expected to be ready for shakedown testing and field trials in 1983.

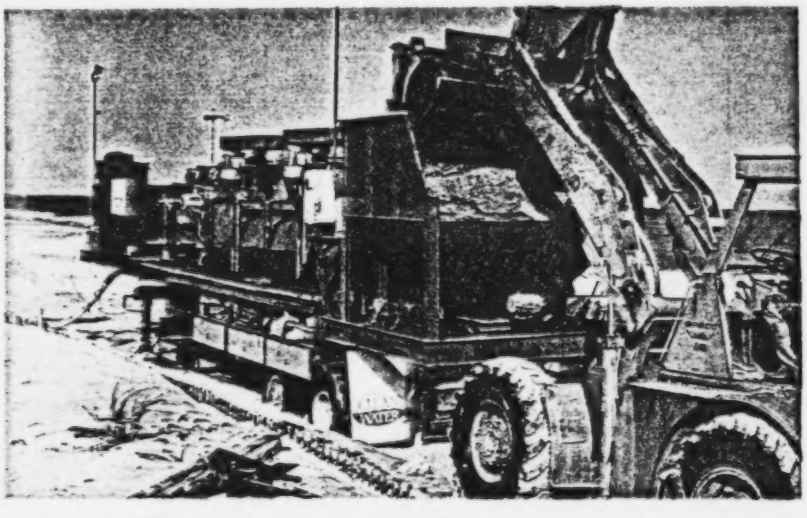

Figure 11. Chemical extractor for separating spilled materials from excavated soils on site.

Mobile In-Situ Soils Treatment System

Where large volumes of subsurface soils are contaminated at spills or hazardous waste sites, excavation of the soil is not economically feasible. A commercially available alternative approach is to flush the soil in place with water. The mobile in-situ soils treatment system (16) offers an innovative, improved technique for treating contaminated subsurface soils in place at reduced costs, in terms of dollars per kilogram of contaminant removed. The technique employs water flushing with additives, and detoxification by chemical reaction.

The system (Figure 12) is mounted on a 13.1-m (43-ft) drop deck trailer and consists mainly of mixing, piping, and pumping equipment. In-situ containment can be accomplished with this system through direct injection of grouting material into the soil around the contaminated area, thereby isolating the area. The contaminants are then treated in place by water-flushing with additives or by other methods such as oxidation/reduction, neutralization or precipitation. Specially prepared solutions of wash water can be delivered into highly contaminated soil through 16 injectors (slotted or perforated pipes which are inserted into a series of holes drilled into the impacted area). A vacuum well-point withdrawal system creates an artificial hydraulic gradient which draws the wash solution from the injectors through

the contaminated soil thereby speeding up the natural groundwater leaching process. The now chemically contaminated wash solution is processed through a mobile water treatment unit where contaminants are removed. Chemical additives are then introduced into the cleansed wash solution which is reinjected into the contaminated area for further treatment.

Preliminary testing of the mobile in-situ soils treatment system has been completed and shakedown testing is now underway. The unit is scheduled for field evaluation in 1983.

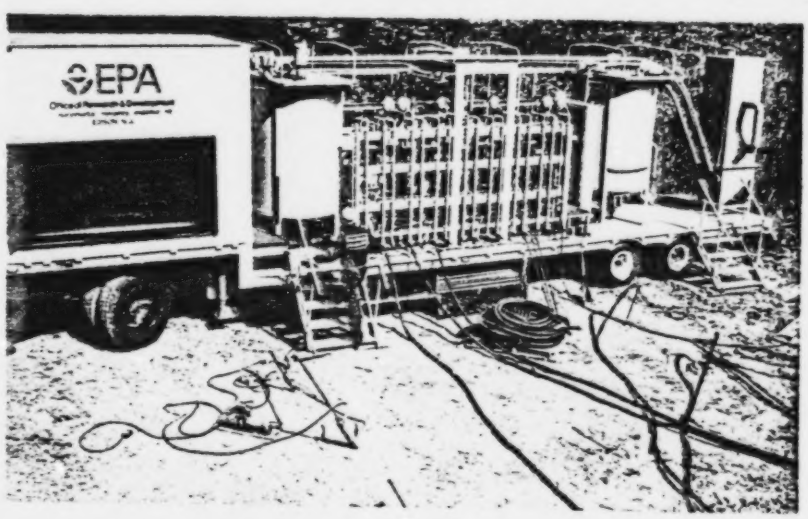

Figure 12. Mobile in-situ soils treatment system for cleaning and detoxifying subsurface contaminatetd soils in place by water-flushing with additives, or by chemical reaction.

Other Technologies

The devices described in the preceding paragraphs are but a few of the items of emergency response hardware developed under the EPA Oil and Hazardous Materials Spills (OHMS) Branch research program. Other outputs of the program worthy of mention include the following:

- A trailer-mounted multi-purpose gelling agent system for solidifying and immobilizing spilled hazardous liquids and preventing their penetration through the soil into groundwater supplies (17,18).

- A pallet-mounted emergency collection bag and pumping system, consisting of a 26,500-liter (7000-gallon) furled Teflon-coated urethane bag and battery-powered or explosion-proof gasoline motor-driven pumps, for temporarily storing spilled hazardous chemicals (10).

- Portable field kits for use by spill response personnel to detect and identify a wide variety of spilled chemicals in waterbodies (19,20).

- Enzyme-based systems for detecting the presence of spilled organophosphate and carbamate pesticides in water (21,22,23).

- A cyclic colorimeter--a device capable of performing opacity-sensitive determinations for the detection of spilled heavy metals in water (24).

- A field test kit for screening the contents of chemical waste drums at uncontrolled disposal sites for the presence of strong oxidizing and reducing agents (25).

- An ultrasonic device for locating sunken insoluble hazardous materials on the bottoms of waterbodies (26).

- A computerized file of case history information which documents past field experiences of actual hazardous material incidents and provides easy retrieval of lessons learned (27).

CONCLUDING REMARKS

The development of effective emergency response technologies to control hazardous chemical releases at spills or waste sites is critical to EPA's mission to guarantee the protection of public health and the environment from the adverse effects of such chemical releases. A point has now been reached where several devices have been designed, constructed, and field tested. More will soon be available for actual use. As new equipment is developed, the OHMS Branch will continue to (a) conduct comprehensive shakedown testing to assure field readiness and reliable performance on a rapid response basis; (b) conduct field trials to demonstrate operational capability and usefulness of the equipment in "real world" emergency situations; and (c) actively encourage commercialization of the new technology by making detailed plans, specifications, and design drawings available to the private sector.

Although the OHMS Branch research program is predominantly hardware oriented, its outputs also consist of technical reports, handbooks, guidance documents, and user manuals on a variety of emergency response-related areas including: protocols for ensuring personnel safety at waste sites and spills; practices for reducing the frequency and severity of spills; techniques for halting the release and spread of contamination to the surrounding water, air, soil and sediments; methods for congealing spilled hazardous liquids and contents of damaged drums; procedures for characterizing the extent of hazardous material releases and for locating subsurface spills; techniques for controlling spillage from impoundments and waste lagoons; methodology for determining cleanup priorities and for evaluating alternative removal techniques; strategies for emergency contingency planning; methods for on-site encapsulation or destruction of hazardous substances recovered at spills or waste sites; and rapid emergency procedures for chemical analyses aboard mobile laboratories.

The technology developed under this program is transferred to the general public via the above documents as well as the biennial National Conferences

on Control of Hazardous Material Spills. EPA takes a lead role in organizing and promoting these conferences which are co-sponsored by other Federal agencies and private industrial organizations such as the U.S. Coast Guard and the Chemical Manufacturers Association, respectively. The Proceedings of these conferences are an excellent means of communicating the developments of the EPA emergency response research program to the user community (28-33).

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